A Stochastic Model for Chemotaxis Based on the Ordered Extension of Pseudopods

Van Haastert, Peter J. M.

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Supporting Material

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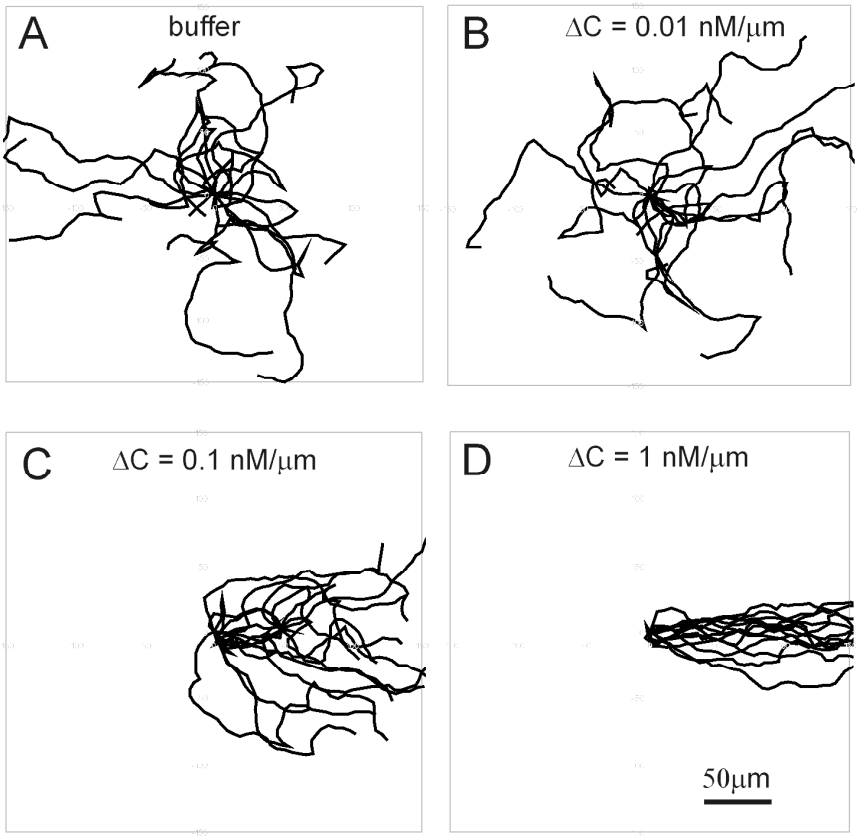
Authors: Peter Van Haastert



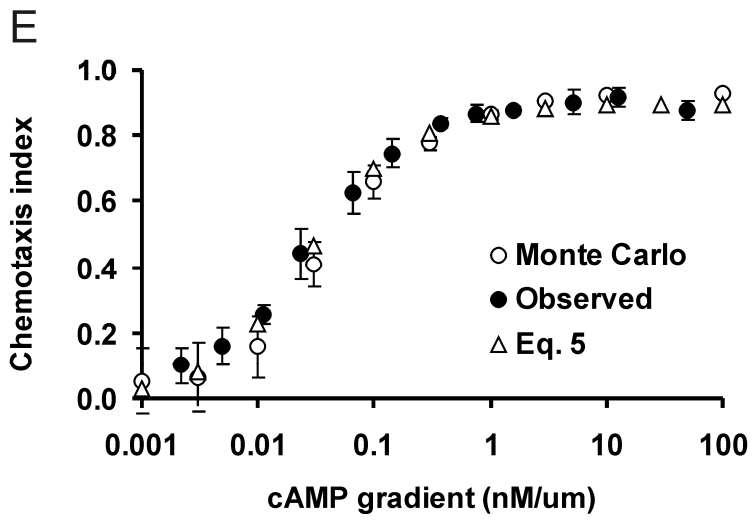


Figure S1. Monte Carlo simulations of chemotaxis. Panels A-D show 14 tracks of cells in buffer or cAMP gradients with different steepness of cAMP gradient, pointing to the right. Panel E presents dose-response curves for Monte Carlo simulations of 10,000 tracks for each gradient, the experimentally observed chemotaxis index of *Dictyostelium* cells, and the calculated chemotaxis index using Eq. 5. The data show the expected mean and SD.

Methods: Pseudopod extension in the absence of external cues is an ordered stochastic event (Van Haastert, P.J.M. (2010) PLoS Comput Biol 6: e1000874). The position of the tip of the formed pseudopodia depends on pseudopod size λ_p, splitting fraction s, Left/Right alternating ratio a, angle between split pseudopodia ϕ and variance of this angle σ_ϕ. Furthermore, during chemotaxis a bias in imposed on the extended pseudopod by the cAMP gradient that is different for splitting and de novo pseudopodia and depend on the steepness of the gradient ∇C , the maximal bias A_j, and the steepness of the gradient inducing half-maximal bias K_j.

A Monte Carlo simulation starts with a random angle α_1 of the first pseudopod and then uses four uniformly distributed random numbers $R_{i,n}$ (i = 1, .., 4) to calculate $\alpha(n)$, the angle of the subsequent nth pseudopod: $R_{1,n} \in [0,1]$ with the decision to split if $R_{1,n} < s$; $R_{2,n} \in [0,1]$ with the decision for alternating splitting if $R_{2,n} < a$; $R_{3,n} \in [0,1]$ for direction of split after de novo with decision right if $R_{3,n} < 0.5$; and $R_{4,n} \in [-180,180]$ for the direction of the de novo pseudopod. These probabilities result in a projected angle of extension, α'_n . The cAMP gradient induces a bias of this projected angle that is given by Eq. 4, which results in a second projected angle $\alpha''_n = \alpha'_n - bias$. Finally, the actual pseudopod direction α_n is drawn from a wrapped von Mises distribution with this projected angle α''_n as mean and the angle σ_ϕ^2 as variance ($\kappa = 1/\sigma_\phi^2$). The obtained α_n and the pseudopod size λ_p are used to calculate the x,y coordinates of the tip of the pseudopodia, followed by a next round of four random numbers and directional *bias* to calculate α_{n+1}.

Parameter settings: The experimentally determined parameters used in the simulations are: pseudopod size λ_p = 5.3 μm; splitting fraction s = 0.92; Left/Right alternating ratio a = 0.75; angle between split pseudopodia ϕ = 55 degrees and variance of this angle σ_ϕ = 20 degrees; Amplitude of bias by splitting and de novo pseudopodia A_s = 0.5 and A_{dn} = 1.0, respectively; Steepness of the gradient inducing half-maximal bias by splitting and de novo pseudopodia K_s = 0.13 and K_{dn} = 1.35 nM/μm, respectively.

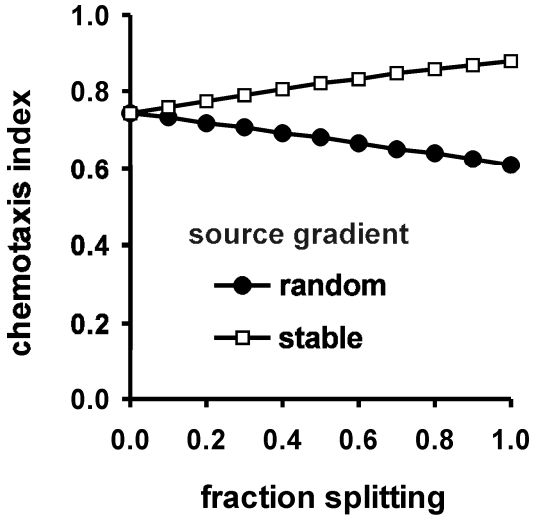


Figure S2. Detection of random or stable cAMP gradients with de novo or splitting pseudopods. *Dictyostelium* cells in their natural habitat are exposed every 5 minutes to a new cAMP gradient, which may come from random directions or from the same direction as the previous wave. For random waves, the direction of the new gradient was assumed to be random (90 degrees) relative to the current pseudopod. For stable gradient the direction of the new gradient was assumed to be at 30 degrees relative to the current pseudopod (at 3 min after passing the current wave the pseudopodia are oriented at about 30 degrees relative to the direction of that wave; see Fig 5C). The figure presents the direction of the pseudopod induced by the new gradient, which was calculated with Eq. 5 for cells with different fractions of splitting pseudopodia. The cAMP gradient of natural waves was assumed to be 2 nM/μm. The results shows that random waves are detected better by de novo pseudopodia, while splitting pseudopods are more sensitive to stable waves.